Africa RISING Technical Report Template

Instruction: *This template should be used for interim and full technical reports.*

Reporting Period

April 2017-February 2018

Section A. Partner Information

A.1. Institution: Institut d'Ecomie Rurale (IER)

A.2. Contact person: Dr Kalifa TRAORE, (Agronomy/Soil sciences), Tel: +22376047556; BP:262, Bamako-Mali; Email: ibosimon_1@yahoo.fr

A.3. Intervention sites, country: Flola, Madina, Mpessoba, Kani

A.4. Other partners:
ICRISAT, IITA, AVRDC, ILRI, AfriqueVerte (AMASSA), Association Malienne d'Eveil et de Developpement Durable (AMEDD), Cooperatives of the Mouvement Biologique du Mali (MOBIOM), Centre d'Appui a l' Autopromotion pour le Development (CAAD).

Section B. Progress/achievements during the reporting period

Excecutive summary of achievements

A study was carried out at Kani and Noupinesso (onfarm) and also, Flola and Mpessoba (technology park) in the Soudano-Sahelian zone of Mali. The main objective was to assess the impact of tillage, soil amendments and leguminous crop , on runoff, soil erosion,

soil moisture and the growth and yield of cotton, sorghum, and fast growing nitogen fixing trees species. Two types of experiment were conducted. The first experiment consisted of two factors implemented in a split plot design. The first factor represented the main plot with two levels corresponding to contour bunding (CB) and no contour bunding (NCB) which was also farmer's practice. The second factor which represented secondary plots was composed of four soil fertilization on cotton (control, organic manure, micro-dose, and recommended dose). Similar trial was laid in four (4) replications for each of the six (6) collaborative farmers. The second experiment, consisted of two tillage practices (CB and NCB) as main plots and three cropping system as secondary plots (sole crop of sorghum , sole crop of soybean, sorghum intercropped with soybean). The same trial was implemented in 4 replications in the field of each of the nine (9) collaborative farmers and in the Technology Park of Mpessoba.

The percentage of runoff rate in NCB plots were 53 to 59% and were decreased by the use of CB to 33 and 41% respectively. Contour bunding increased water table dynamic at Noupinesso village. The distance of water table to soil surface decreases and reach a minimum value of 2.44 m in the CB plot and 4.15 m in the NCB plot while it was only 0.86 m in the plot close to the layout of the watershed . Contour bunding increased soil moisture in the 0-100 cm horizon for all sites. The different was high at the horizon 60-100 cm and at the end of rain season. Soil horizon (0-100 cm) under trees was slightly humid than outside trees.

CB plot out yielded the NCB one in all of the measured parameters. In Kani, manure increased cotton seed yield (Bourama Dembele's field), biomass (Barnabe Traore 's field), height, diameter (sekou Berthe's field) by 32, 55, 29 % and 30 % respectively . Growth and production of cotton in the micro-dose (T3) and recommended doses (T4) treatments were significantly ($p < 0.05$) higher than the ones with manure application. T4 and T3 increased cotton seed yield by 67 % and 66 %, biomass yield by 72 % and 69 % in Remon Sanou's field. The use of CB technology significantly affected the growth and yields of cotton for all the six trials. In fact, cotton yield was 81 % higher in CB plot than compare to the NCB in the field of Barnabe Traore. Concerning cotton height, and increase of

46 % was observed with the CB plot compared to the NCB one in Remon Sanou ‘s field. With a value cost ratio (VCR) less than 2.0, the treatment micro-dose was more economically profitable for the six trials.

Intercropping sorghum with soybean increased sorghum growth and yields for all the nine trials. In some case, yield of sorghum intercropped with soybean (2325 kg ha^{-1}) produced more than the double of sorghum sole crop (1138 kg ha^{-1}). The use of CB affected sorghum and soybean grain and biomassgrowth and yield for all the nine trials. +50% on sorghum grain and biomass were observed with CB and +30% for height and diameter.

CB technology increased *Gliricidia sepium* and *Leucaena leucocephala* growth at all the sites. Gliricidia height, diameter, and crown radius were increased by 35, 25 and 40 % respectively. For Leucaena, the icreases were 58, 69, and 50 % respectively.

B.1. Achievements (progress and/or results) against outputs towards outcome 1

Project Outcome 1: Outcome 1: Farmers and farming communities in the project area are practicing more productive, resilient, profitable and sustainably intensified crop-livestock systems linked to markets.				
Output 1.1: Research products for more productive, intensive, diverse, profitable and resilient crop (cereals, legumes, vegetables), livestock (sheep, goats, cattle, poultry and pigs) and integrated crop-livestock farming systems are identified and disseminated to farmers through development partners.	Planned Activities 1. 2. 3.	Planned Milestones 1. 2.	Deviation from Planned Milestone 1. 2. 3	Achievements towards Output

Output 1.2: Integrated management practices and innovations to improve and sustain productivity and ecosystems services of the soil, land, water and vegetation resources are developed and disseminated with farmers and development partners in the intervention communities.	Planned Activities	Planned Milestones	Deviation from Planned Milestone	Achievements towards Output
	1. Test and disseminate land, soil and integrated land-soil technologies and practices to improve and sustain productivity and ecosystems services at the farm and landscape/watershed levels	1.i. Data on water table levels, soil moisture content, erosion and runoff is monitored 1.ii. Recommendations for future research 1.iii. Recommendations for farmer practices in the region/ for scaling (if not relevant explanation why not) 1.iv. Manuscript on erosion control for publication	1.i erosion was not determined because of money shortage. Negociation are going on to see if an aggreement can be found for laboratories analysis 2. 3	1.i Measurements were done and data uploaded to dataverse 1.ii done 1.iii. report and brief on the CB technology have been done 1.iv. writing of the manuscript is going on
	2. Integrated management technologies and practices to improve and sustain productivity and ecosystems services of the soil, land, water and vegetation resources are developed and disseminated with farmers and development partners in the intervention communities	2.i Report (Interim report submitted to ICRISAT) 2.ii. Data on agronomy and trees 2.iii. Recommendation of Best agro-forestry technology in combination with CBT 2.iv Farmer exchange visit		2.i. Report done 2.ii Data send for upload to dataverse 2.iii see report (done) 2.iv replaced by the farmers open field day (done)

	. 3.			
Output 1.3: Labor-saving and gender-sensitive technologies in target areas to reduce drudgery while increasing labor efficiency in the production cycle delivered.	Planned Activities 1. 2. 3.	Planned Milestones 1. 2.	Deviation from Planned Milestone 1. 2. 3	Achievements towards Output

Tables and graphs in support of achievements

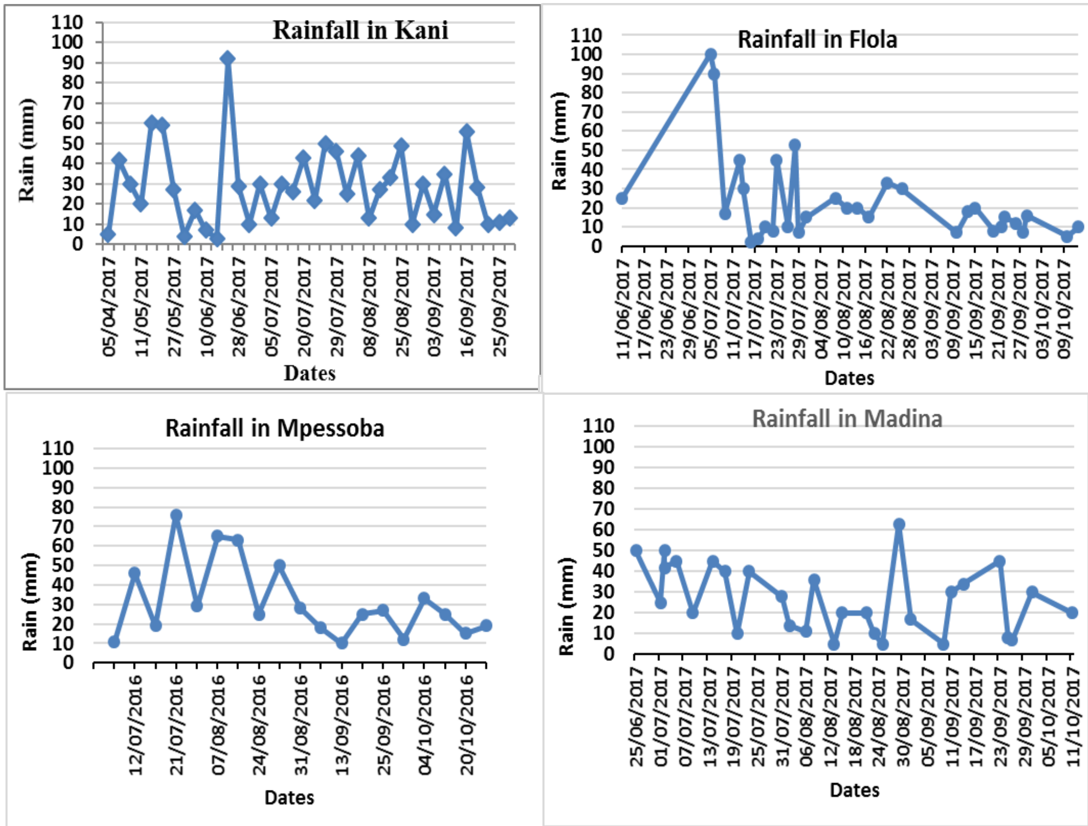


Figure 1: Rainfall in the studied sites, Southern Mali, 2017

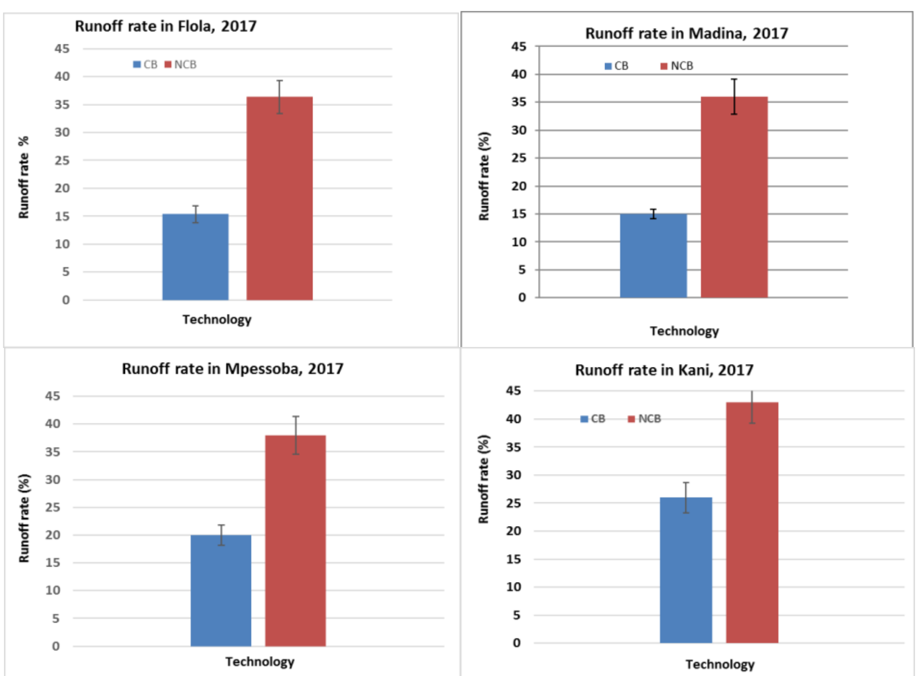


Figure 2: Runoff rate in Flola, Mpessoba, Madina and Kani

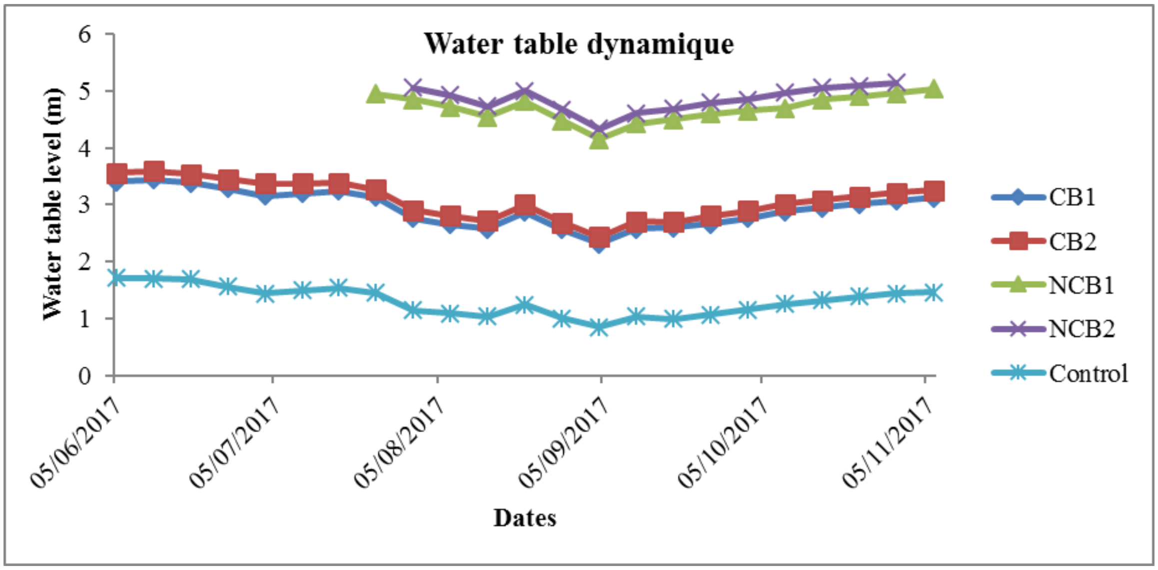


Figure 3: Water table dynamic at Noupinesso (number affected to CB or NCB means replication 1 and 2)

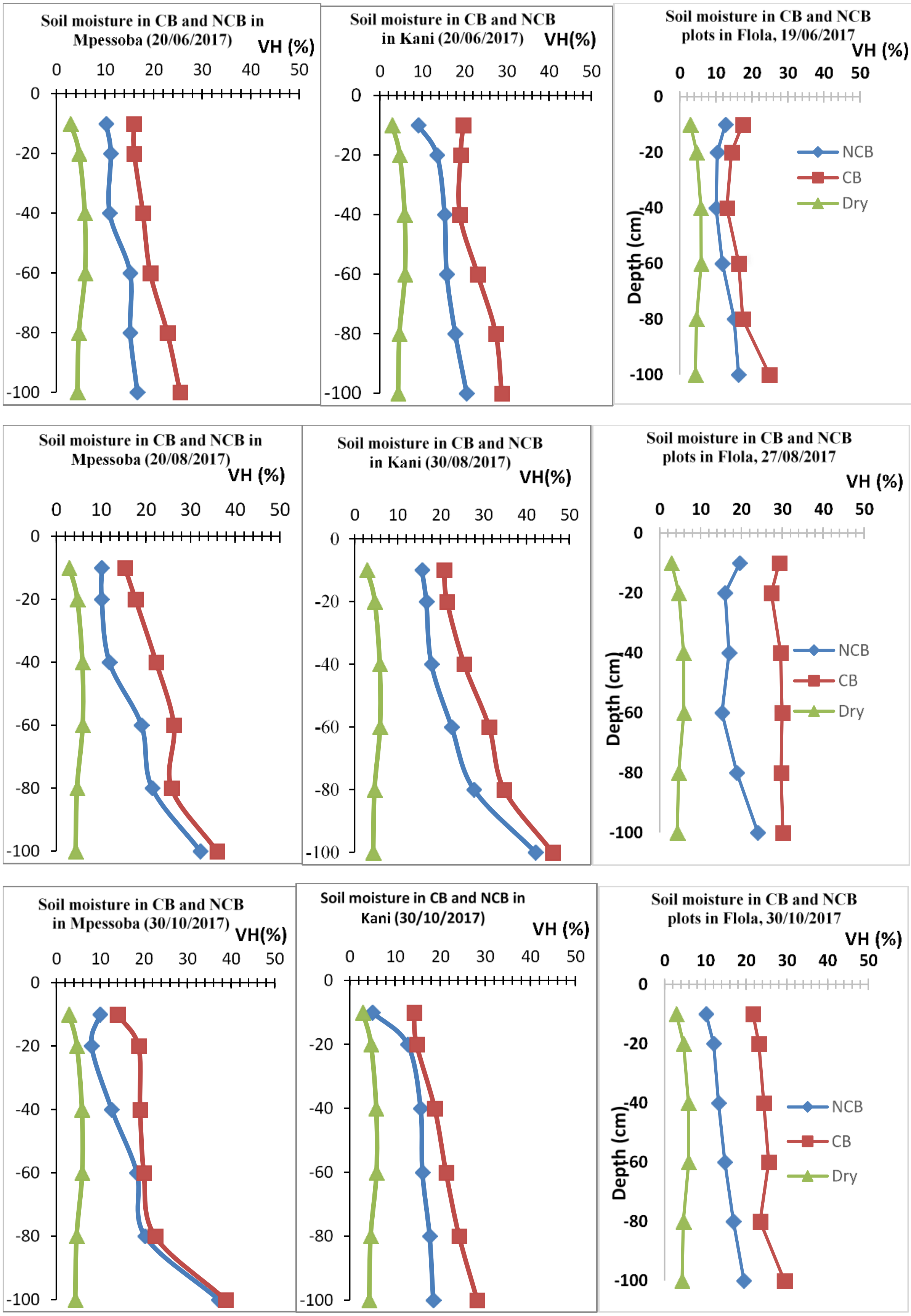

Soil moisture in CB and NCB in Mpessoba (20/06/2017)
VH (%)
Soil moisture in CB and NCB in Kani (20/06/2017)
VH(%)
Soil moisture in CB and NCB plots in Flola, 19/06/2017
VH (%)
Depth (cm)
NCB
CB
Dry
Soil moisture in CB and NCB in Mpessoba (20/08/2017)
VH (%)
Soil moisture in CB and NCB in Kani (30/08/2017)
VH(%)
Soil moisture in CB and NCB plots in Flola, 27/08/2017
VH (%)
Depth (cm)
NCB
CB
Dry
Soil moisture in CB and NCB in Mpessoba (30/10/2017)
VH(%)
Soil moisture in CB and NCB in Kani (30/10/2017)
VH (%)
Soil moisture in CB and NCB plots in Flola, 30/10/2017
VH (%)
Depth (cm)
NCB
CB
Dry

Figure 4: Soil moisture in kani, Mpessoba and Flola, southern Mali, 2017

Table 1: Cotton yield in Kani, Southern Mali, 2017

	Cotton yield kg/ha					
	Soil amendments					
FARMERS	**T1**	**T2**	**T3**	**T4**	**F.pr (0.05)**	**L.s.d**
Sékou Berthé	1092	1133	1512	1488	0.013	204.6
Salif Berthé	929	1088	1567	1708	0.063	602.1
Barnabé Traoré	1125	1238	1683	1754	0.021	336.5
Bourama Dembélé	1208	1604	1971	1867	0.002	148.8
Remon Sanou	1533	1604	2542	2567	0.023	635.6
Sita Berthé	888	1104	1629	1629	0.003	206.3
	Soil conservation					
	CN	**NCB**	**F.pr (0.05)**	**L.s.d**	**CV(%)**	
Sékou Berthé	1446	1167	0.009	144.6	4.9	
Salif Berthé	1575	1071	0.033	425.8	14.3	
Barnabé Traoré	1867	1033	0.002	237.9	7.3	
Bourama Dembélé	1981	1344	<.001	105.2	2.8	
Remon Sanou	2690	1433	0.003	449.5	9.7	
Sita Berthé	1419	1206	0.19	145.9	4.9	

Table 2: Cotton Biomass yield in Kani, Southern Mali,2017

	Biomass yield kg/ha					
	Soil amendments					
FARMERS	**T1**	**T2**	**T3**	**T4**	**F.pr (0.05)**	**L.s.d**
Sékou Berthé	1554	1833	2667	3125	<.001	155.678
Salif Berthé	1733	1900	2775	3000	0.012	559.972
Barnabé Traoré	1854	2867	3283	3492	0.029	882.6
Bourama Dembélé	2188	2771	3692	3754	0.024	860.6
Remon Sanou	2604	2638	3754	3708	0.037	847.5
Sita Berthé	1658	1950	2896	2879	0.002	304.1
	Soil conservation					
	CN	**NCB**	**F.pr (0.05)**	**L.s.d**	**CV(%)**	
Sékou Berthé	2667	1923	<.001	110.081	2.1	
Salif Berthé	2675	2029	0.014	395.960	7.5	
Barnabé Traoré	3756	1992	0.003	624.1	9.6	
Bourama Dembélé	3919	2283	0.003	608.6	8.7	
Remon Sanou	4402	1950	<.001	599.2	8.4	
Sita Berthé	2852	1840	<.001	215.0	4,1	

Table 3: Cotton plant height in kani, Southern Mali , 2017

	Crop height (m)					
	Soil amendments					
FARMERS	**T1**	**T2**	**T3**	**T4**	**F.pr (0.05)**	**L.s.d**
Sékou Berthé	0.805	1.035	1.320	1.305	0.006	0.1717
Salif Berthé	0.860	0.880	1.160	1.260	0.007	0.1487
Barnabé Traoré	1.015	1.205	1.480	1.480	0.032	0.2852
Bourama Dembélé	0.965	1.110	1.390	1.460	0.025	0.2671
Remon Sanou	0.985	1.100	1.505	1.385	0.039	0.3253
Sita Berthé	0.9850	1.1350	1.3650	1.4000	<.001	0.03375
	Soil conservation					
	CN	**NCB**	**F.pr (0.05)**	**L.s.d**	**CV(%)**	
Sékou Berthé	1.235	0.997	0.007	0.1214	4.8	
Salif Berthé	1.107	0.973	0.026	0.1051	4.5	
Barnabé Traoré	1.450	1.140	0.016	0.2017	6.9	
Bourama Dembélé	1.405	1.058	0.01	0.1889	6.8	
Remon Sanou	1.475	1.012	0.008	0.2300	8.2	
Sita Berthé	1.2500	1.1925	0.005	0.02387	0.9	

Table 4: Diameter of cotton plant in kani, Southern Mali , 2017

	Crop diameter (mm)					
	Soil amendments					
FARMERS	**T1**	**T2**	**T3**	**T4**	**F.pr (0.05)**	**L.s.d**
Sékou Berthé	7.25	8.29	12.21	13.50	0.003	1.595
Salif Berthé	7.71	10.04	13.75	14.13	<.001	0.968
Barnabé Traoré	11.29	12.96	16.50	17.30	0.139	6.357
Bourama Dembélé	10.0	11.4	18.1	16.9	0.164	9.63
Remon Sanou	9.96	11.17	16.92	15.29	0.69	5.534
Sita Berthé	9.79	11.09	13.91	14.09	0.021	2.292
	Soil conservation					
	CB	**NCB**	**F.pr (0.05)**	**L.s.d**	**CV(%)**	
Sékou Berthé	10.81	9.81	0.051	1.127	4.9	
Salif Berthé	12.29	10.52	0.004	0.684	2.7	
Barnabé Traoré	16.65	12.38	0.057	4.495	13.8	
Bourama Dembélé	16.9	11.3	0.077	6.81	21.5	
Remon Sanou	15.86	10.82	0.029	3.913	13.0	
Sita Berthé	12.56	11.88	0.270	1.621	5.9	

Table 5: Capsule number by cotton plant in Kani, Southern Mali , 2017

	Mean of capsules number/plant					
	Soil amendments					
FARMERS	**T1**	**T2**	**T3**	**T4**	**F.pr (0.05)**	**L.s.d**
Sékou Berthé	7	7.00	13	13.00	0.003	1.837
Salif Berthé	6.00	8	13.00	13	0.026	4.109
Barnabé Traoré	7.00	9.00	13.00	10.00	0.145	5.663
Bourama Dembélé	7.00	10	14	14	0.058	4.990
Remon Sanou	6.00	10	15	14	0.054	5.918
Sita Berthé	6	9	12.00	13	0.054	4.990
	Soil conservation					
	CN	**NCB**	**F.pr (0.05)**	**L.s.d**	**CV(%)**	
Sékou Berthé	11.25	8.25	0.005	1.299	5,9	
Salif Berthé	10.25	9.25	0.353	2.905	13.2	
Barnabé Traoré	12.00	7.50	0.037	4.004	18.3	
Bourama Dembélé	13.00	8.75	0.031	3.528	14.4	
Remon Sanou	13.25	8.50	0.036	4.185	17.1	
Sita Berthé	10.50	8.75	0.213	3.528	16.3	

Table 6: Value to cost ratio (VCR)

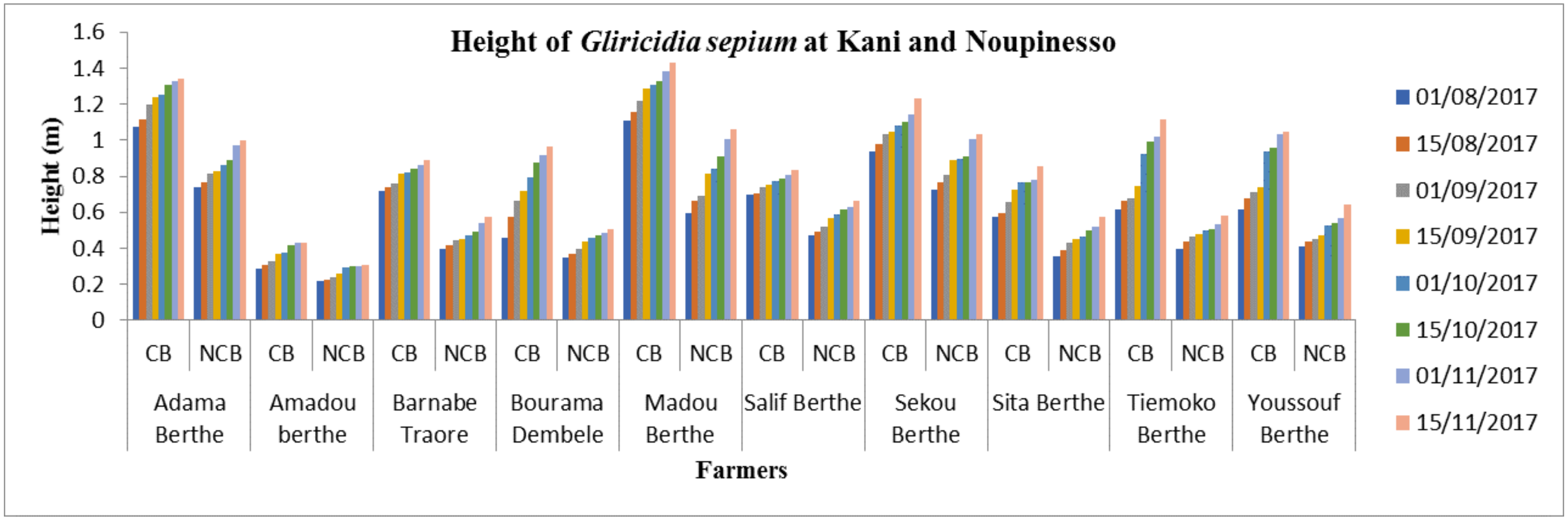
FARMERS	**SOIL AMENDMENTS**	**VCR**
	T2	0
	T3	2
Sekou Berthe	T4	1
	T2	2
	T3	3
Salif Berthe	T4	2
Barnabe Traore	T2	1

	T3	3
	T4	2
Bourama Dembele	T2	4
	T3	4
	T4	2
Remon Sanou	T2	1
	T3	5
	T4	3
Remon Sanou	T2	2
	T3	4
	T4	2

Table 7: Grain yield and Land Equivalent Ratio (LER) of sorghum intercropped with soybean in Kani, Southern

	Grain yield (kg/ha)								
FARMERS	**SSC**	**S XSb**	**SbSC**	**SbXS**	**CB_ S**	**NCB_S**	**CB_Sb**	**NCB_Sb**	**LER**
Youssouf Berthé	1138	2325	1229	1783	1817	1646	1771	1242	3
Oumar Berthé	1354	2117	1408	1804	2062	1408	1792	1421	3
Tiéméko Berthé	596	992	1108	1483	1012	575	1504	1088	3
Boukary Berthé	671	1096	1054	1429	1138	629	1479	1004	3
Amadi Bathily	483	867	1333	2212	858	492	2283	1262	3
Mahamadou Bathily	608	1096	1325	2346	1117	588	2304	1367	4
Blaize Sanou	408	813	1346	1846	720.8	500	2012	1179	3
Basil Sanou	588	900	1125	1825	908	579	1992	958	3
Mpessoba	1091	1620	1146	2554	1539	1172	2242	1458	4

SSC=sorghum sole crop; Sb = sotbean; X= intercropped



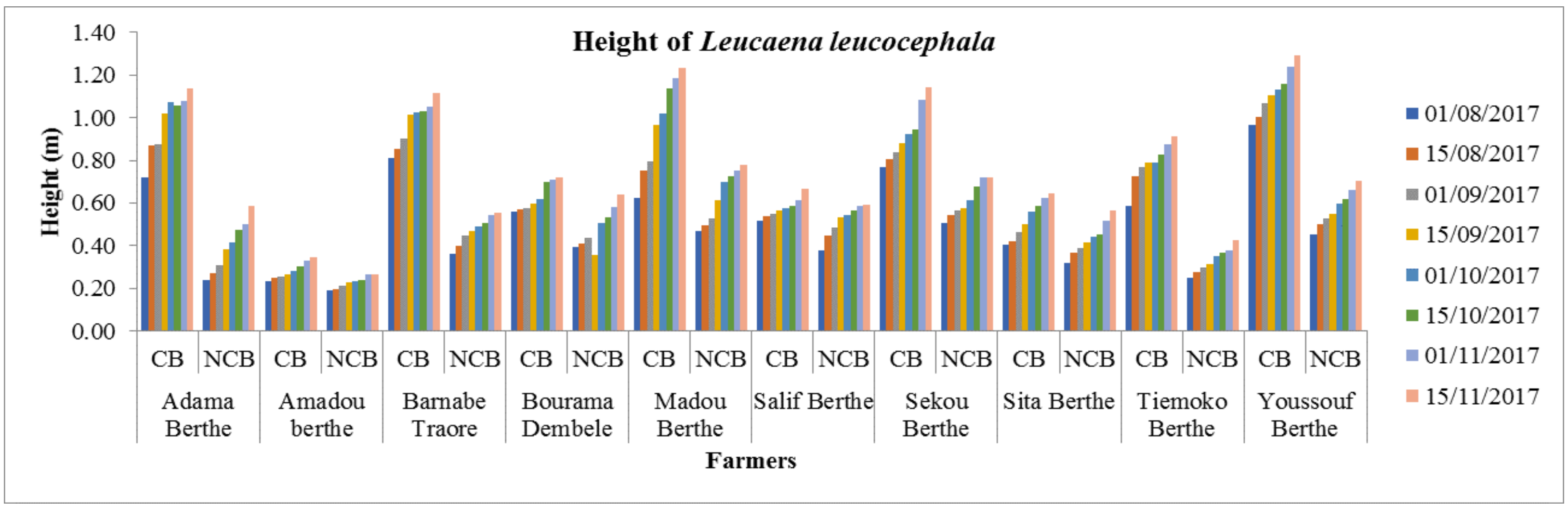
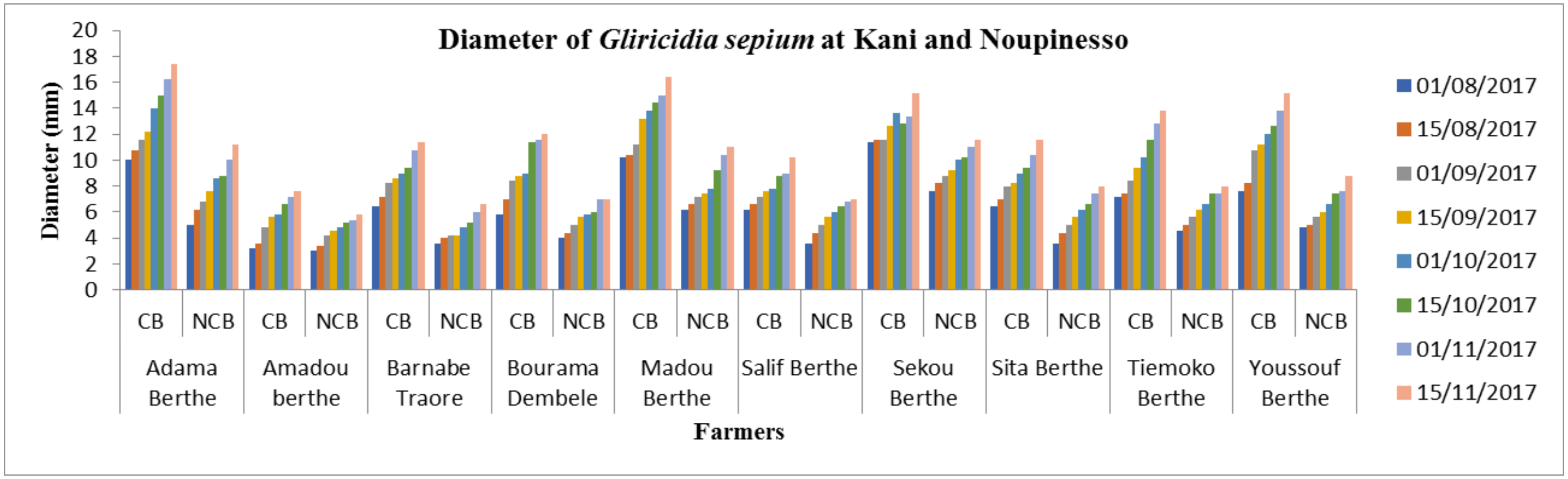


Figure 5: Height of *Gliricidia sepium* and *Leucaena leucocephala* at kani and Noupinesso, southern Mali, 2017



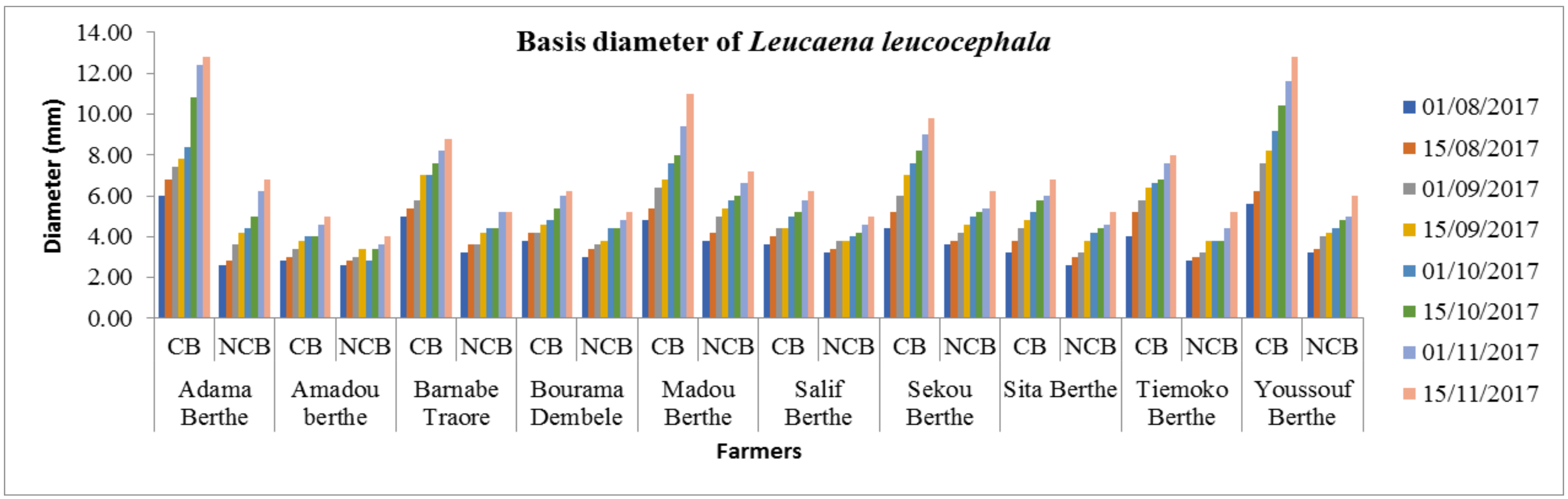


Figure 6: Basal diameter of *Gliricidia sepium* and *Leucaena leucocephala* at kani and Noupinesso, southern Mali, 2017

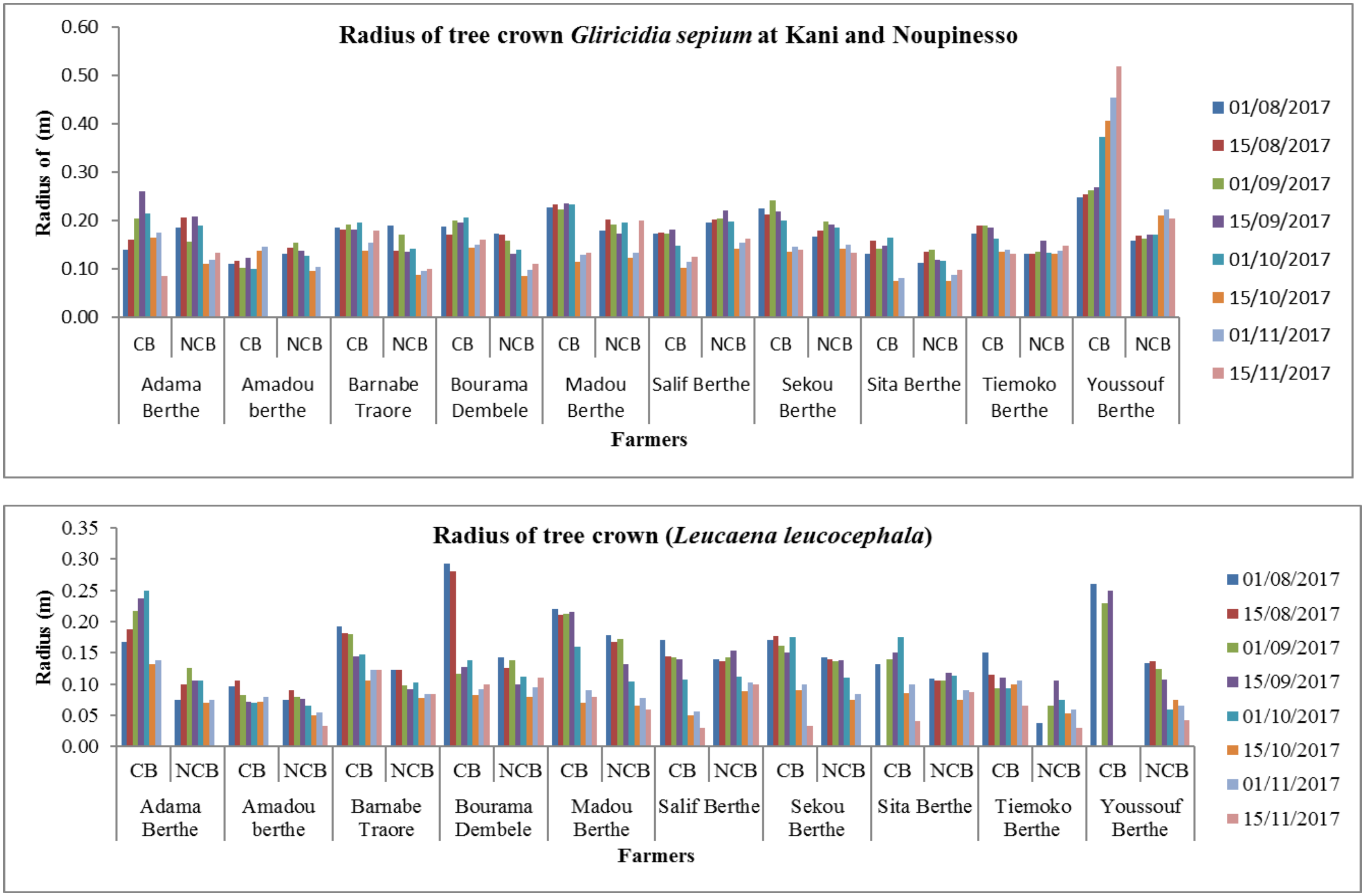


Figure 7: Crown radius of *Gliricidia sepium* and *Leucaena leucocephala* at kani and Noupinesso, southern Mali, 2017

Analysis, interpretation and discussion of achievements

1. Rainfall:

In Kani, Flola and Mpessoba, the big rainfall event were observed in June and July while it was in August at Madina (Figure 1). Flola and Kani recorded the biggest rainfall event, 100 and 90 respectivelly. This situation do not lead automatically to higher runoff rate in kani for instance, explaining that it depend also on rain intensity and duration as reported by casenave and Valentin (1992).

2. Runoff rate

Considering the 4 sites, runoff coefficient varies from 15 to 20 % in CB plots and 35 to 42% in NCB ones (Figure 2). Runoff is greater in farmer's field in Kani than the technology parks. This situation is explained by the slope which was close to 3% while in the technology park it was about 1%. Increasing runoff according to slope was widely reported by Roose (2008).

3. Water table dynamic at Noumpinesso

Contour bunding technology has and important effect on water table dynamic at Noupinesso. Water table increased in volume ie the distance of groundwater to soil surface decreases and reached a minimum value of 4.3 m in NCB and 2.4 m in CB at the beginning of September. For the area near the outlet, the minimum value observed was 0.86 m. After this period, the groundwater level dropped and the distance to the soil surface increased during the rest of the season for all the measurement tubes until November (Figure 3). This finding is in agrrement with those reported by kablan et al (2008) during his works in Mali.

4. Soil moisture at Mpessoba, Kani, and Flola

For soil moisture analysis, the dates were chose to represent the beginning, the middle and the end of rain season.

Figure 4 showed that soil moisture was always high in the CB plot than the NCB plot and increase regularly from up to down of the profile. In June at the beginning of rain season, a maximum mean soil moisture of 25 % was observed in the CB plot at 100 cm depth while the corresponding value for the NCB was 15%. In the 60 cm upper soil layers, soil moisture was not greater than 20 %.

In August, when the rain was frequent and the drainage deep, mean soil moisture in deeper horizon was greater than 30% and all the profile was wet and the difference between CB and NCB was visible along the profile. For instance , in Flola the mean soil moisture along the profile was 59% greater in the CB (29.3%) compared to the NCB (18.4).

At the end of the cropping season, the drainage was deep with less water, but from 60 to 100 cm mean soil moisture in CB plot was 25%. Also, a mean difference of 10% was observed between CB and NCb at these soil layers. This situation can be important for crop sowed late in the season but also for trees to continue surviving during the dry season.

5. Agronomic trials

5.1. Soil conservation and soil fertilisation

The effect of CB and soil amendments on cotton yield were presented in table 1. Cotton yield was significantly influenced by CB and soil amendments. In fact, the CB plot significantly ($p<0.05$) recorded higher cotton yield than the NCB for all the six trials and the highest one was 2690 kg ha^{-1} in Remon Sanou's field**.** The application of recommended amendment T4 (5 t ha^{-1} OM + 200 kg ha^{-1} CC + 50 kg ha^{-1} Urea) and the micro-dose T3 (2.5 t ha^{-1} OM + 100 kg ha^{-1} CC + 25 kg ha^{-1} Urea) has significantly ($p<0.05$) increased cotton yield than the control T1 (no amendment) and the T2 (5t ha^{-1} OM). Remon Sanou's recorded again the best cotton yield with 2567 kg ha^{-1}.

Table 2 showed biomass yield for the six trials, the results are similar to those of cotton yield. In fact, 4402 kg ha^{-1} of biomass was recorded for CB plot in Remon Sanou 's field.

Soil tillage and soil amendment significantly ($p<0.05$) increased cotton height (table 3) like cotton biomass and yield. Fertilisation has significantly ($p<0.05$) increased cotton diameter in three trials among six. Expeted, in Sita Berthé's field, CB showed significant effect ($p<0.05$) on cotton diameter. The greater diameter were recorded with T3 (18.1 mm) in Bourama Dembele's field and CB (16.9 mm) (table 4).

Table 5 showed the number of capsule by cotton plant. Fertilization, significantly ($p<0.05$) affected cotton capsule number for all trials exepted the one implemented in Barnabe Traore 's field. Concerning CB, only the trials in Salif and Sita Berthe 's field showed no statistically difference in capsule number.The highest number of capsules by plant was noticed in the field of Remon Sanou in T3 (15 capsules per plant). For CB plot, the field of

Bourama Dembele and Remon Sanou showed the highest capsules number (13 capsules per plant).

Table 6 shows the value to cost ratio (VCR) for the six trials. The highest values were observed with the T3 of all trials, varying from 4 to 5.

5.2. Soil conservation and intercropping

Table 7 showed that sorghum and soybean grain yield were significantly ($p<0.05$) influenced by CB and intercropping. Sorghum intercropped with soybean produced greater grain yield compared to sorghum sole crop, the same trend was observed with soybean for the nine (9) trials. Intercropping of sorghum and soybean give an enormous advantage (LER equal at least to 3) for all trials (LER > 1 means advantageous intercropping).

5.3. Effect of CB technology on growth of *Gliricidia sepium* and *Leucaena leucocephala* at Kani, Noupinesso, and Technology Park of Mpessoba

From June to middle of November the CB increased growth of both *Gliricidia sepium* and *Leucaena leucocephala* at the three research sites. In November, when the plants of Kani and Noupinesso were 5 month old, the mean highest values of 1.43 m and 17.4 mm were respectively recorded for Gliricidia and Leucaena plant height and basal diameter in CB plot. The corresponding values were 1.06 m and 11.2 mm in the NCB plot (figure 5 and 6). Trees crown were larger in CB plots than NCB from August to September, after this period, leaves started falling and the growth become less visible on the ground (figure 7).

6. Discussion

6.1. Impact of CB technology on runoff and runoff coefficient at Kani and the Technology Park of Mpessoba

At Kani as well as in the Mpessoba Technology Park, the runoff was always greater in the NCB plot than in the CB for all the rains of the season. The system of CB technology is a holistic landscape approach to managing water and capturing precipitation at the watershed scale. Our findings corroborate those of Kablan *et al,* (2008) who reported that the main roles of CB are: capture and recycling of precipitation in treated fields in the watershed, and assist to the evacuation of excessive rainfall and surface fluxes destructive that can trickle into the fields as the application of CB reduced rain runoff from 22 to 61%.

Runoff rate varies from 15 to 25% in the CB plots and from 35 to 43% in the NCB plots. It was more important at Kani than in the Mpessoba Technology Park. This situation can be explained by the higher slope (3%) and gravellous soil in kani while in the technology park the slope was 1.5% and soil loamy sand. Akbarimehr and Naghdi (2012) reported that the length of the slope has a significant effect on flow volume; however, further analysis has shown that increasing the length of the slope can lead to increased runoff ($p < 0.05$); the slope may affect the volume of runoff; in addition, there was a linear relationship between the volume of runoff, the length of the slope, and the inclination of the slope. This conclusion was also made by Jordan-Lopez *et al.* (2009) who reported that steeper slopes in percent may increase runoff volume.

6.2. Impact of CB technology on water table dynamic at Noupinesso

The water table increases in volume ie the distance to the soil surface decreases which attained a minimum value of 2.44 m for the CB plot, 4.15 m in the NCB plot and 0.86 m next the outlet of the watershed at the beginning of September. This situation could be explained by a deep infiltration of the maximum rainfall observed in August to increase the recharge of groundwater. This conclusion corroborated that of Kablan *et al* (2008) who reported that the CB recharged groundwater from 1 to 26% during the rainy season in Fansirakoro.

6.3. Effect of CB technology on soil moisture at Kani, Noupinesso and the Technology Park of Mpessoba

At Kani, Noupinesso and Mpessoba soil moisture was always higher in the CB plot than in the NCB plot. The CB technology is applied for reduction of runoff, which therefore increases infiltration and soil moisture as demonstrated by the work of Dembélé (2013) who reported an average moisture difference of 11 % when comparing CB and NCB plots. At Kani, with the use of CB, soil moisture was always higher under Gliricidia and Leucaena tree crown than outside. In fact, trees planted on the crest of the main contour line benefited from runwater it captured like similarly evoqued by Kablan *et al.* (2008) who mentioned that CB increased soil moisture in areas explored by plant roots by 16% to 64% compared to NCB. Our results are also in agreement with those of Doumbia *et al*, (2012) who mentioned 17% water storage in CB plots in the 80-160 cm profile horizons and

12.7% in the first 80 cm. At the end of the season, soil moisture was at least 25% explaining a real water supply potential for the trees of the park land as reported by Kablan *et al.* (2008) when assessing the effects of CB on soil water dynamic in Siguidolo and Fansirakoro.

6.4. Effect of soil amendments on cotton growth and production at Kani and Noupinesso

The use of manure (T2) without other amendments significantly ($p < 0.05$) increased cotton growth and production than the control. Manure increased cotton yield by 32 % in Bourama Dembele's field, biomass yield by 55 % in the field of Barnabe Traore, cotton height by 29 % and cotton diameter by 30 % in the trial of Sekou Berthe. Application of organic amendments to a cropping system has shown an increase of crop yield as well as improvement of soil nutrient level. This observation supports the finding of Duncan and Jayne (2016), demonstrating a significant yield response to composted feedlot manure, composted poultry manure and raw feed lot manure obtained in cotton production. This potentially indicated that the use of the manure provided soil with resilience to be able to recover more quickly and better meet crop nutrient demand after this eventas reported by Bationo and Mokwunye (1991).

Application of manure do not significantly ($p < 0.05$) produced cotton than application of micro-dose (T3) and recommended dose (T4). The T4 and T3 increased cotton yield by 67 and 66 % respectively. Muhammad *et al.* (2014) reported in similar study that, application of recommended dose of NPK produced higher seed cotton yield (2660 kg ha^{-1}) , followed by ½ NPK+FM (farm manure)-Fermented (2523 kg ha^{-1}) and differed significantly from other treatments.

6.5. Effect of contour bonding CB technology on cotton growth and production at Kani and Noupinesso

The use of CB technology significantly affected the growth and yields of cotton for all the six trials, in the field of Barnabe Traore and Remon Sanou, cotton yield was, 81 % and 46 % respectively higher in CB plot than the NCB one. CB increases soil nutrient and available soil moisture for crop uptake and enhanced crop growth as reported by Li *et al.*,

(2008). In a related study, Khlifi (2008), showed that dry matter yield in the CB plot was higher than that measured in the control.

6.6. Effect of soil amendments on cotton value cost ratio

It is reported that any treatment that had a VCR greater than 2 is profitable. Heerink (2005) stated that technically, VCR greater than 2 would imply profitability of fertilizer as long as other inputs were not altered as the use of fertilizer. Among the soil amendments, the micro-dose treatment gave the best profitability as indicated by the VCR in the range of 2 to 4 for the six trials. In spite of its contribution to increased crop yield, the micro-dose was less costly than recommended fertilizer doses. Micro-dose application on sorghum improves famers' average income which was found to be 100,385 and 184,625 FCFA/ha respectively with local and improved sorghum varieties, representing a yield increase of 57% and 160% respectively compared to recommended fertilizer application (IDRC, 2014). With the application of rain water harvesting (RWH) techniques, profitability of micro-dosing increases to 284 % with the improved variety. These represent a VCR of 1.3 for the local sorghum variety and 3.8 for the improved one. When micro-dosing was associated with RWH techniques, the VCR increased to 2.6 to 6.9 for local and improved varieties respectively (IDRC, 2014). The VCR for the T4 was lower than that of sole manure because the prices of inorganic fertilizers were high.

6.7. Evaluation of sorghum-soybean association cultivation.

Intercropping of sorghum and soybean increased sorghum growth and yields for all the nine trials. In some trials, yields of sorghum intercropped with soybean got more than the double of those of sorghum sole crop. Intercropping system in the nine trials was profitable with LER varying from 3 to 4.

A general assumption in intercropping cereals with legume crops is that legume, when, associated with specific Rhizobium, may have most of its N to supplied through fixation of atmospheric N, leaving the soil available N for the companion cereal (Saberi, 2018). There is evidence that leguminous plants can benefit the intercrop cereals in the same season through N excretion and nodule decomposition (Bonetti, 1991).

These results corroborate that of Saberi (2018) who indicated that the mean comparison of dry forage of sorghum associated to soybean also increased by 24.01 % in Gorgan and

26.12 % in Aliabaad, and LER of 1 row sorghum 1 row soybean was better than sole cropping sorghum.

6.8. Effect of CB technology on intercropping sorghum-soybean.

The use of CB increased sorghum and soybean growth and yields for all nine trials. In fact, sorghum and soybean grain and biomass yield were increased by +50 % and their height and diameter by +30. CB as a result of increasing rainfall infiltration, increased water availability, improving crop growth and reducing erosive runoff as shown in long-term studies initiated by Gigou *et al.* (2006) and soil water storage studies (Kablan *et al.,* 2008). These findings document increased soil water content resulting in increased crop yields. Yields may increase as much as 50 % for millet, sorghum, and maize (Gigou *et al.,* 2006). Traore *et al.,* (2004) reported that the effects of CB on millet yield have been variable. Compared to the control, CB increased millet grain yield in Mali by 27 % in 1998, 2 % for 1999 and finally 60 % in 2000. The yield increase was attributable to moisture conservation capacity of the CB technology. This idea was in agreement with those of Falkenmark *et al.,* (2001) and Irshad *et al.,* (2007), who mentioned that soil moisture conservation is vital for smallholder cropping systems . The moisture conserved in soil profile supplies water to crop at the end of rainy season when plants are flowering and filling their grains.

6.9. Impact of CB technology on the growth of fast growing fodder trees species.

CB technology increased *Gliricidia sepium* and *Leucaena leucocephala* growth at the three sites of research as reported by Craig and John (2006) who mentioned that the initial growth of Gliricidia is rapid (up to 3 m in the first year). Gigou *et al,* (2000) mentioned that, with CB application, water balance is improved and soil profiles were wetter, which is favorable to the associated trees. The height, diameter, and crown radius of Gliricidia were increased by +35 %, +25 %, and +40 % respectively; and +58 %, +69 %, and +50 for Leucaena respectively. In semi-arid climate such in southern Mali, CB reduced soi1 erosion and substantially increase rainfall infiltration, which resulted in increasing growth of crops and trees as mentioned by Traore *et al.*, (2006) who concluded that shea butter tree and other species inside cropped fields benefit from the increased water due to CB, which aids both growth of existing trees as well as the germination and establishment of young trees.

References

Akbarimehr. M, Naghdi. R. (2012). Assessing the relationship of slope and runoff volume on skid trails (Case study: Nav 3 district). JOURNAL OF FOREST SCIENCE, Department of Forestry, Faculty of Natural Resources, University of Guilan, Somehsara, Iran. 58, 357–362.

Bationo, A. and Mokwunye, A.U. (1991). Role of manures and crop residues in alleviating soil fertility constraints to crop production: With special reference to the Sahelian and Sudanian zones of West Africa. Fertiliser Research 29: 117–125.

Bonetti R. (1991). Transferência de nitrogênio do feijão para o milho consorciado: avaliação pelo método de diluição isotópica do 15N e efeito da associação micorrízica. 63 f. Tese (Doutorado em Agronomia) - Escola Superior de Agricultura Luiz de Queiroz, Piracicaba.

Casenave A. et Valentin C. (**1992**). A runoff classification system based on a surface features criteria in semi-arid areas of West Africa. *journal of hydrology* **130**: 231-249.

Craig R. Elevitch and John K. Francis. (2006). Species Profiles for Pacific Island Agroforestry www.traditionaltree.org. Gliricidia sepium (gliricidia) Fabaceae (legume family). gliricidia, Mexican lilac, mother of cocoa, Nicaraguan cacao shade, quick stick, St. Vincent plum, tree of iron (Eng-lish); immortelle, lilas étranger (French); madre de cacao (French, Spanish); rechesengel (Palau). Ver. 2.I

Duncan Weir and Jayne Gentry. (2016). The impact of various organic amendments on yield and soil properties, 203 Tor Street, Toowoomba, Qld, 4350 , Ph: 0410 518 214

Falkenmark, M., Fox, P., Persson, G. and Rockström, J. (2001). Water harvesting for upgrading of rainfed agriculture – Problem analysis and research Needs. SIWI Report No11. Stockholm International Water Institute, Stockholm, Sweden. 94pp

Gigou, J., Traoré, K., Giraudy, F., Coulibaly, H., Sogoba, B. and Doumbia, M. (2006). Aménagement paysan des terres et réduction du ruissellement dans les savanes africaines. In Agricultures (2006) 15(1): 116–122.

Gigou J., K.B. Traoré, H. Coulibaly, M. Vaksmannl, M. Kouressg. (2000). Aménagement en courbes de niveau et rendements des cultures en région Mali-sud : CIRAD, BP1813, Bamako, Mali : IER-Laboratoire Sol-Eau-Plante, BP43 8, Bamako, Mali. 19-391-404 pdf.

Irshad, M., Inoue, M., Ashraf, M. and Al-Busaidi, A. (2007). The management options of water for the development of agriculture in dry areas. Journal of Applied Sciences 7(11): 1551-1557.

Jordan-Lopez A., Martinez-Zavala L., Bellinfate N. (2009): Impact of different parts of unpaved forest roads on runoff and sediment yield in a Mediterranean area. Science of the Total Environment, 407: 937–944.

Kablan R, Yost RS, Brannan K, Doumbia MD, Traoré K, Yoroté A, et al. "Aménagement en courbes de niveau", Increasing rainfall capture, storage, and drainage in soils of Mali. Arid Land Res Manag. 2008;22(1):62–80.

Khlifi, S. (2008). Contribution à l'étude d'impact des aménagements antiérosifs sur la fertilite des sols en Tunisie Centrale. Agrosolutions 19 (2).

Li, Y.X., Tullberg, J.N., Freebairn, D.M., Mclaughlin, N.B. and Li, H.W. (2008). Effects of tillage and traffic on crop production in dryland cropping systems: II. Long-term

simulation of crop production using PERFECT model. Soil and tillage research 100(1-2): 25-33.
Muhammad Anwar-ul-Haq, Javaid Akhtar1, , Muhammad Saqib, Amjad Hussain and Tahir Hussain. (2014). Integrated use of farm manure amineral fertilizers to maintain soil quality for better cotton (*gossypium hirsutuml.*) production. pak. j. agri. sci., vol. 51(2), 413-420; ISSN (print) 0552-9034, issn (online) 2076-0906. http://www.pakjas.com.pk
Roose E. (2008). Soil erosion, Conservation and restoration: A few lessons from 50 years of research in Africa. In: Carmello D. and Edoardo C. (eds), Soil Erosion Topic2, Advances in GeoEcology, pp. 160-180.
Saberi AR. Biomed J Sci & Tech Res. (2018). Comparison of Intercropped Sorghum-Soybean Compared to its Sole Cropping. ISSN: 2574-1241
Traoré K.B., G. McCarthy, J.S. Gigou*, M.D. Doumbia, A. Bagayoko, R.S. Yost, H. Konaré, L. Dioni, H. Coulibaly, A. Sidibe et R.A. Kablan** * Cirad-Tera. (2006). Aménagement en courbes de niveau et conservation du carbone. TA60/15,34398 MONTPELLIER Cedex 5, téléphone: 04-67-59-38-89 fax :04-67-59-38-38, e-mail : jacques.gigou@cirad.fr ** IER, Labo .sol, eau, plantes, BP. 262, Bamako, Mali, fax : (223).22.37.75, courriel : madu.doumbia@ier.ml. 23-268-577 pdf.

Highlight SI indicators and their defining metrics

- The use of CB on farmer's field in kani, produced 1830 kg ha^{-1} of cotton compared to the NCB with 1209 kg ha^{-1}. The increase was 51% corresponding to 621 k ha^{-1}. Cotton biomass was 3379 kg ha^{-1} with CB and et 2003 kg ha^{-1} without. The increase was 1376 kg ha^{-1}, corresponding to 68%.

  Efficiency of inputs was also improved. In fact, use of CB allow a gain of 520 kg ha^{-1} of cotton corresponding to 46% compared to farmer's practice. For cotton biomass yield, the gain was 1012 kg ha^{-1} corresponding to 52%.

- The yields of sorghum and soybean were always greater when intercropped in comparison to sole crop. Productivity of sorghum in intercropping was 1620 kg ha^{-1} compared to 1091 kg ha^{-1} in sole crop i.e a difference of 48% corresponding to 529 kg ha^{-1}. Productivity of soybean in intercropping was 2554 kg ha^{-1} and 1146 kg ha^{-1} in sole crop corresponding to more than two folds.

- Run off was always greater in NCB plots than in CB explaining why the runoff rate varies from 15 to 20 % in CB plots and 35 to 42% in NCB ones. This situation lead to water availability by improving infiltration, erosion decrease and finally securisation of crop production. The increase of water infiltration lead to the recharge of water table explained by the decrease of the distance to soil surface to only 2.44 m for the CB plot while 4.15 m was observed in the NCB plot in the watershed level at the beginning of September.

- The height of Gliricidia and Leucaena reached 1.5 m in CB plot for only 5 month growth while in the NCB it was 0.6 m. The carbone sequestered in these trees is important for environment since it mitigated green house gaz such as CO_2. So, at least 100 kg of above ground dry biomass was produced on each contour bunding of 100 m^2.

B.6. Synthesis

Use the SI indicator results to illustrate how outputs under the 4 outcomes are defining your innovation/technology.

The use of CB showed clearly positive effect on crop yield and biomass production. This is done through water and nutrient conservation for crop developpement. Cropping systems were improved by crop diversification through intercropping of sorghum and soybean which was highly profitable for farmers (LER higher than 1). Increasing always crop productivity (grain , residues, fodder) by the use of CB is a way to ensure food security in changing west African climate but also a way to produce manure by feeding animals. Crop residues were also positively influenced by the use Fast growing nitrogen fixing trees species show better developpement for forage production but alsoe better environmenet condition by mitigation greenhouse gas through carbon sequestration. These advantages of the technology must be sustain in household level by training a technical team in villages so that they can continue after the project live time. This have not be done because of funding problem but some collaborative farmers were trained on related isuues. However, 43 agroforestry and CB based demonstrative plots were impmlemented in the field of 43 farmers.The plots were unformally visited by many passing farmers and good feed back were heard from them.

B.7. Capacity Building

Tabulate: Type/title of training, where, when, number and category of people trained

Type/title	**Location**	**Period**	**Men(Adults) >40 years**	**Men(youths) 25-40 years**	**Total**
Piquetage	Kani	2 days	18	6	24
	Noumpinesso	2 days	15	4	19
Construction of the main contour line by oxen	Kani	3 days	Same farmer	Same farmer	Same farmer
	Noumpinesso	3 days	Same farmer	Same farmer	Same farmer
Maintenance of the system	Kani	2 days	Same farmer	Same farmer	Same farmer
	Noumpinesso	2 days	Same farmer	Same farmer	Same farmer
Total	2 villages	14 days	33	10	**43**

43 collaborative farmers (30 adults and 13 youths) were trained on the piquetage of the contour line, construction of the main contour line and maintenance of the entire system. However, farmers were not trained on how to determine the contour line using water or automatic level. This training was planned for next season because of the early start of the rainy season and late release of the project fund. The training done, allow discussion between farmers of the same household showing they have common interest which is a sign of good social cohesion.

Section C. Problems/challenges and measures taken

Funding process sometimes causes problems of data availability for scientific writing. For example, many soil and water samples were sent to the Soil –Water- Plant laboratory of IER for analysis. Although few of them are now being analysed, the all samples related to the PhD thesis cannot be analysed because the project is ending and we are exious about the continuation of the hesis already going on with already a huge quantity of data.

Section D. Partnership/linkages with other projects

This activity is part of the activities related to dissemination of integrated land-soil technologies and practices to improve and sustain productivity and ecosystems services at the farm and watershed level. In fact, the use of contour bunding can lead to changes through trees growth or/and regeneration, water table rise, appearance of new activity (for instance vegetable gardening because of water availability in wells, etc.).
This activity is linked to improve crop and livestock breeding practices to help agricultural activities and also small ruminant fattening. For instance, coppicing can be done next year during the plowing, ridging and sowing operations using oxen. This is important because at this period there is allways forage shortage for animals.

Section E. Lessons learned

Farmers are ready to go with technologies responding to their daily constraints and having a quick and visible impact in a short term basis and CB is one of such technology.

Section F. Monitoring and Evaluation

F.1. Feed the Future indicators

Tabulation with the following columns: (i) FtF indicator, (ii) Annual target (iii) Progress toward target, (iv) Segregation, (v) explanation for over/under achievement (only for full report)

Info must also be provided to the Africa RISING Economist and/or to the project M&E specialist when needed for reporting to USAID FTFMS (usually during October each year) using PMMT.

Activity: Improving crop livestock productivity and household income through the use of contour bunding and agroforestry options

FtF indicator	Annual target	Progress toward target	Segregation	Explanation
1.1.producers' organization	1	1	1	All men
women's groups,				
New	1	1	1	All men
1.2. Ha of land under improved technology	20	20	1	All men
crop genetics (maize, p'pea, sorghum, cotton,bambara, g/nut, livestock forages)	1	4	1	All men
soil-related	1	1	1	All men
water management	1	1	1	All men
climate mitigation or adaptation	1	1	1	All men
new	20	20	1	All men
Male	40	43	1	All men
1.3. Producers	2	2	1	All men
Male	2	2	1	All men
Female				
1.4.Producers' organization	2	2	1	All men
New/continuing	2	2	1	All men
1.5. Number of farmers appling new technology	40	43	1	All men
Sex	1	1	1	All men
Male	40	43	1	All men
Female				All men
1.8.Producers' organization	2	2	1	All men
Male	2	2	1	All men
Female				All men
1.9.Producer organization	2	2	1	All men
New	1	1	1	All men
1.10.1 phase 1- Number of technology	1	1	1	All men
1.10. Phase 2-Number of technology	2	3	1	All men
1.11.Male				All men
Female				All men

Activity: Field measurement and nutrient quality assessment of runoff, erosion, soil water content, water table and vegetation from field to watershed scale under different land use and land management practices.

FtF indicator	Annual target	Progress toward target	Segregation	Explanation
1.1.producers' organization	1	2	1	All men
women's groups,				
New	1	1	1	All men
1.2. Ha of land under improved technology	4	4	1	All men
crop genetics (maize, p'pea, sorghum, cotton,bambara, g/nut, livestock forages)	2	2	1	All men
soil-related	1	1	1	All men
water management	1	1	1	All men
climate mitigation or adaptation	1	1	1	All men
new	2	2	1	All men
Continuing	3	3	1	All men
Sex	1	1	1	All men
Male	5	5	1	All men
1.3. Producers	4	4	1	All men
Sex	1	1	1	
Male	4	4	1	All men
female				
1.4.Producers' organization	2	2	1	All men
New/continuing	2	2	1	All men
1.5. Number of farmers appling new technology	4	4	1	All men
Sex	1	1	1	All men
Male	4	4	1	All men
Continuing	4	4	1	All men
1.8.Producers' organization	2	2	1	All men
Sex	1	1	1	All men
Male	4	4	1	All men
1.9.Producer organization	2	2	1	All men
New /continuing	2	2	1	All men
1.10.1 phase 1- Number of technology	1	1	1	All men
1.10. Phase 2-Number of technology	2	2	1	All men
1.11.Male				All men
Female				All men

F.2. Custom indicators

Tabulate (i) Custom indicator, (ii) Annual target, (iii) Progress toward target, (iii) explanation for over/under achievement

Activity: Improving crop livestock productivity and household income through the use of contour bunding and agroforestry options

Custom indicator	Annual target	Progress	Explanation
2. number of on farm demonstration established	40	43	Enthousiasm of farmer about the technologyy
3. Field day	1	1	
4.Youthand women; youth; women	15	15	
7.Number graduate; MS, New	1PhD, 1Msc	1PhD, 0	Funding problem
8. Reports	2	2	
9. Poster	1	0	Short last
10. Radio and TV			

Activity: Field measurement and nutrient quality assessment of runoff, erosion, soil water content, water table and vegetation from field to watershed scale under different land use and land management practices

Custom indicator	Annual target	Progress	Explanation
2. number of on farm demonstration established	2	2	
3. Field day	1	1	
4.Youthand women; youth; women	2	10	Willingness to improve knowledge
7.Number graduate; MS, New	2 Msc	0	Funding problem
8. Reports	2	2	
9. Poster			
10. Radio and TV			

Section G. Success stories

Farmers were found of fast growing nitrogen fixing trees species combine with CB because the demand was as much as greater than what we could provide. In the future,

farmers can be trained on how to establish trees nursery to meet the demand in the communes.